

# **Simulation of the ARGO Observing System**

I.V. Kamenkovich and E.S. Sarachik  
University of Washington, Seattle, WA

## **Project Summary**

The ARGO array currently consists of 3000 instruments that make vertical profiles of temperature and salinity every 10 days over the depth range of 1500 meters. The array is rapidly being brought to full strength, and a comprehensive assessment of the limitations of the ARGO observing system is urgently needed.

The main goal of our study is to examine how well the ARGO observing system determines the state of the global upper ocean. We sample and reconstruct oceanic fields from ocean general circulation models (GCMs), in gradually more realistic sequence of simulations. By quantifying errors in the reconstructed fields, we estimate accuracy of the ARGO observing system, and therefore directly address NOAA's Program Plan for *Building a Sustained Ocean observing System for Climate*.

This project is conducted at the University of Washington, Seattle, Washington.

## **Accomplishments**

We have (with Drs. Wei Cheng and D.E. Harrison) been looking at the expected performance of the ARGO observing system for the ocean. The main goal of the activities during the FY 2007 was to quantify the effects of oceanic advection on the expected performance of the ARGO system. During the FY 2007 we completed the analysis with the coarse-resolution model and focused our efforts on the eddy-resolving simulations.

### **Coarse-resolution studies**

The global ocean model used in this study has  $2^\circ$  resolution in both latitude and longitude; see Kamenkovich (2005) for the model description. The atmospheric forcing used to drive the model is derived from observation-based estimates. Daily values for the 2-meter air temperature and humidity, 10-meter wind speed, and zonal and meridional components of the wind stress are taken from years 1979-2001 of the NCEP-NCAR reanalysis. Climatological monthly values are used for all other atmospheric variables and freshwater fluxes. The simulated ocean state is as realistic as can be expected in a coarse-resolution model. However, because of the coarse resolution, the intensity of the boundary currents is underestimated and the mesoscale eddies are not resolved. The effects of the oceanic advection on the ARGO system in reality are expected to be even stronger than in this model.

In these simulations, 3,000 ARGO floats are advected with the GCM-simulated velocities at 1500m depth during most of the time. Every 10<sup>th</sup> day, a simulated float surfaces, while taking the temperature and salinity (T/S) profile; it then spends 8 hours at the surface, where the float is advected by the surface currents. A float becomes “lost” if it enters a shallow region. Resulting data are used to reconstruct temperature and salinity of the ocean, using objective analysis.

This year activities were mainly focused on the expected accuracy of reconstruction of the upper-ocean stratification. In particular, we analyzed the mixed-layer depth (MLD), thermocline depth, and upper ocean heat content. In this report, we present the results for MLD; our conclusions for other variables are qualitatively similar.

Figure 1 shows the differences between the reconstructed and original GCM-simulated MLD for March; hereafter, we refer to these differences as “errors” in reconstruction. The reconstructed March MLDs exhibit significant errors in the Northern North Atlantic where the MLD is extremely deep due to the formation of the North Atlantic Deep Water (Fig.1a). The mixed layer is also deep (Fig.1a) and the reconstruction errors are large (100-150m, Fig.1b) in the regions immediately north of the Gulf Stream and Kuroshio (Fig.1a). These regions are characterized by large errors in all analyzed fields, including temperature, salinity, heat content and thermocline depth.

In October, the deepest mixed layer, in nature and in this GCM, is found in the Antarctic Circumpolar Current (ACC), south of Australia (Fig.2a). This is the region of the winter-time formation of the Subantarctic Mode Water. The errors in reconstructed MLD are, however, surprisingly small here (Fig.2b). In contrast, the errors are significantly larger at the locations of concentrated ACC currents, where the mixed layer is not necessarily the deepest.

We conclude that the vicinities of concentrated ocean currents correspond to the largest errors in the reconstructed fields. In these regions, the gradients in the mapped fields are sharp and the corresponding spatial variation scale is much shorter than in the rest of the World Ocean. The standard density of the ARGO array is not sufficient to resolve the fronts associated with these currents.

### **Eddy-resolving simulations of the North Atlantic**

To investigate the effects of mesoscale variability on the accuracy of the ARGO system, we carried our analysis in a high-resolution regional model of the North Atlantic. High horizontal resolution (1/8° resolution in latitude/longitude) permits realistic simulation of the Gulf Stream and mesoscale eddies. The objective is two-fold: (i) to evaluate the expected performance of the ARGO system in the presence of intense oceanic currents; (ii) to analyze the effects of the mesoscale variability on the performance of the ARGO system.

The model has 30 levels in the vertical. The topography is realistic on a coarse 1°x1° grid; the total depth of the ocean is 3,000 meters. Initially, 250 ARGO floats are evenly

distributed in the model domain; the floats are then advected by GCM-simulated currents. For the analysis, we used 9 years of high-resolution data from the model.

We begin by analyzing the effects of advection by the intense but steady currents. In our first experiment, the floats are advected by the time-mean velocities, and all mesoscale variability is effectively filtered out. In agreement with our previous coarse-resolution experiments, the regions of the fast advection correspond to the largest systematic biases in the reconstructed fields. In particular, in the vicinity of the North Atlantic Current, the reconstructed MLD is shallower than in the original GCM data.

Next we analyze the effects of the mesoscale variability on the performance of the ARGO system. In our second experiment, the ARGO floats are advected by the full velocities, which include mesoscale eddies simulated by our model. In Figure 3b, we show the difference in the absolute values (magnitudes) of errors between the standard run with full advection and the run with the mean advection only. The mesoscale variability results in the noticeable increase in the error magnitudes throughout the entire domain. The vicinity of the North Atlantic Current is characterized by the particularly large increase in the error magnitude (20-50m).

To further quantify effects of advection, we conduct the third experiment, in which the magnitude of mesoscale variability is amplified by a factor of 2.5. This amplification factor was chosen to bring the variance in the simulated sea-surface height closer to the observed one. As a result of the amplification, the biases in the simulated fields increase everywhere in the domain (Fig.3c). The largest change is seen within the Labrador Current, and near the Cape Hatteras.

More frequent sampling results in the increase in the error magnitudes in the vicinity of the North Atlantic Current (Fig.3d). Vecchi and Harrison (2006), in their study of the Indian Ocean, observe a similar effect of more frequent sampling and attribute it to the increased convergence/divergence of the floats when they are brought to the surface more frequently. In the rest of the domain, the effects of the more frequent sampling are small.

### **Significance of results**

The results clearly demonstrate the importance of oceanic advection in affecting the expected performance of the ARGO observing system. In the vicinity of sharp oceanic fronts, the coarse spatial resolution of the ARGO data results in significant errors in the reconstructed fields. We emphasize the need for additional, dense spatial sampling in the western oceanic boundaries and ACC, as well as in the regions characterized by intense mesoscale variability. More frequent sampling, on the other hand, is unlikely to improve performance of the ARGO system within these regions. Mesoscale variability has a noticeable degrading effect on the ability of the ARGO system to reproduce the oceanic state.

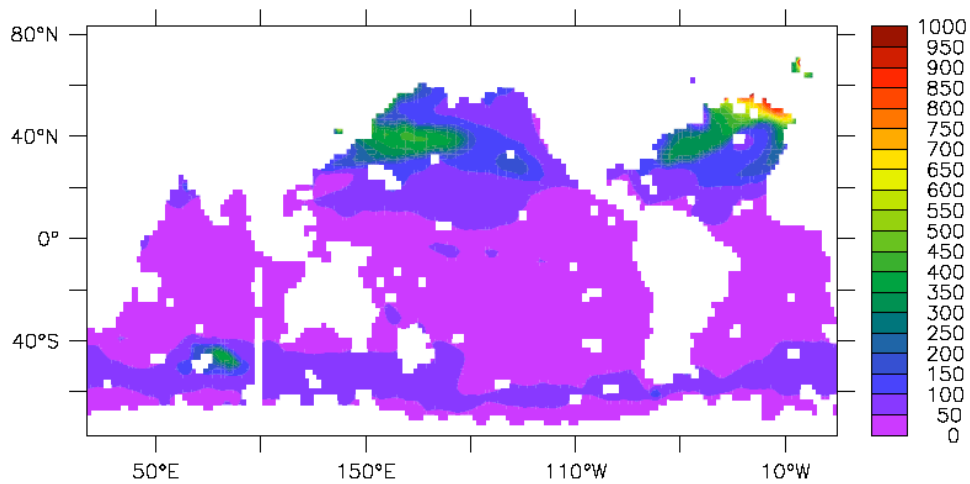
## References:

Kamenkovich, I.V., 2005: "The role of daily surface forcing in setting the temperature and mixed layer structure of the Southern Ocean", *J. Geophys. Res.*, **101**, C07006, doi:10.1029/2004JC002610

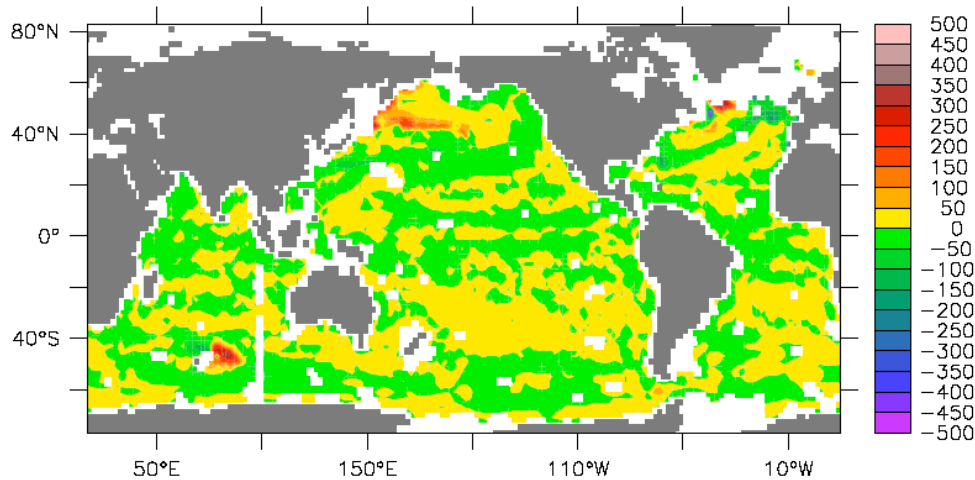
Vecchi, G.A., and M. Harrison, 2006: "An observing system simulation experiment for the Indian Ocean", *J. Climate*, in press.

## Figures

(a)

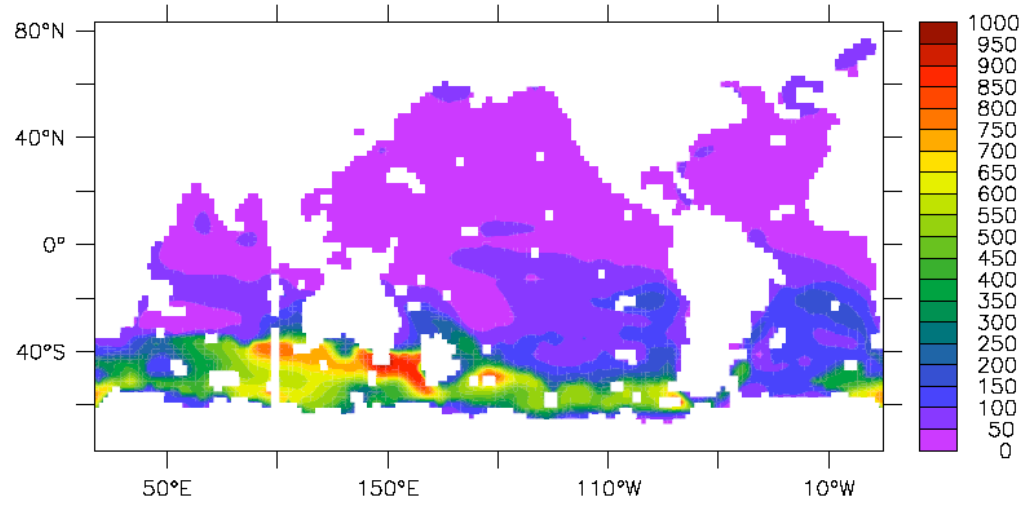


(b)

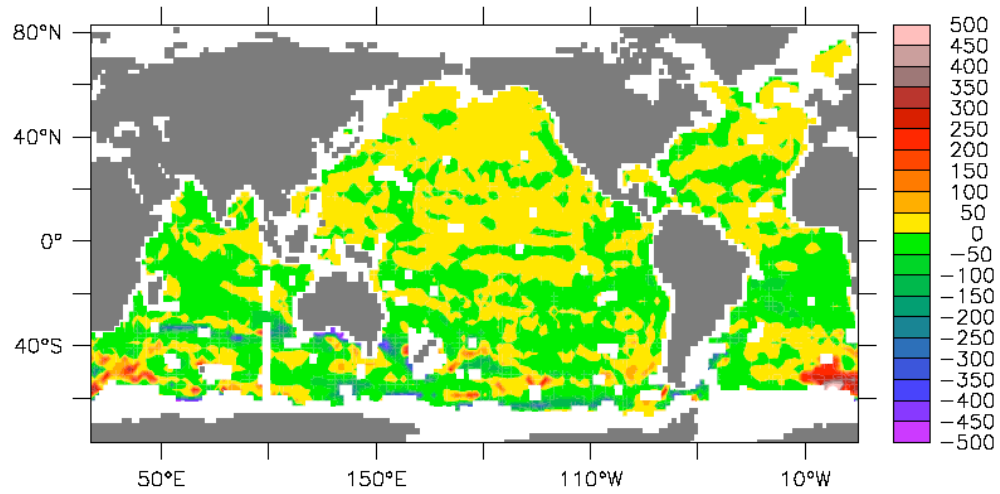


**Figure 1:** (a) The reconstructed mixed-layer depth (MLD) in March. (b) Difference between the reconstructed and original GCM-simulated MLD. The white areas indicate grid points rejected due to the large formal errors of the objective mapping routine.

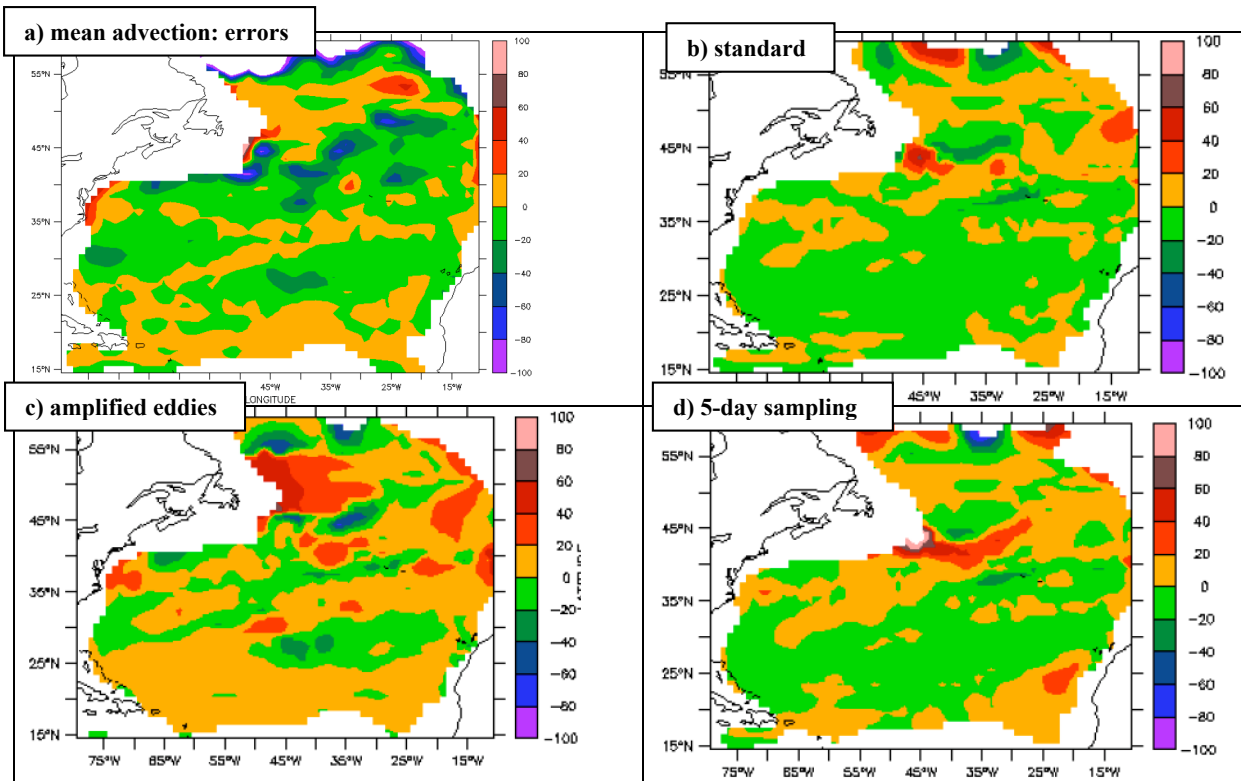
**(a)**



**(b)**



**Figure 2:** (a) The reconstructed mixed-layer depth (MLD) in October. (b) Difference between the reconstructed and original GCM-simulated MLD. The white areas indicate grid points rejected due to the large formal errors of the objective mapping routine.



**Figure 3:** Effects of eddies on the errors in the reconstructed MLD in the eddy-resolving model. **(a)** The difference between the reconstructed and original GCM-simulated fields; the run with the mean advection (no eddies). **(b)-(d)**: The difference in the magnitude of errors (see text) between the runs with the full (eddy+mean) advection and the run with the mean advection only. **(a)** standard run; **(c)** run with the eddy variability amplified by a factor of 2.5; **(d)** run with sampling every 5 days.